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Jc932 U.S. PTO 09/29/00

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PTO/SB/05 (4/98)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	678-529 (P9530)
First Inventor or Application Identifier	Hye-Jeong KIM et al.
Title	System and Method for Compensating Timing
Express Mail Label No.	EL484186784US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, DC 20231

Jc675 U.S. PTO 09/677085 09/29/00

1. [X] * Fee Transmittal Form *(e.g., PTO/SB/17)*
   (Submit an original and a duplicate for fee processing)
2. [X] Specification [*Total Pages* 25]
   (preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) *(35 U.S.C. 113)* [*Total Sheets* 9]
4. Oath or Declaration [*Total Pages* 2]
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 C.F.R. § 1.63(d))
   (for continuation/divisional with Box 16 completed)
   i. [ ] DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. [ ] Microfiche Computer Program *(Appendix)*
6. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [X] Assignment Papers (cover sheet & document(s))
8. [ ] 37 C.F.R.§3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
9. [ ] English Translation Document *(if applicable)*
10. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
13. [ ] * Small Entity Statement(s) *(PTO/SB/09-12)* [ ] Statement filed in prior application, Status still proper and desired
14. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
15. [X] Other: Check for $846.00 (filing fee)
    Check for $40.00 (recording fee)

16. If a **CONTINUING APPLICATION**, *check appropriate box, and supply the requisite information below and in a preliminary amendment*
[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: ______/______
Prior application information: Examiner ______ *Group / Art Unit:* ______
For CONTINUATION or DIVISIONAL APPS only : The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by **reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.**

17. CORRESPONDENCE ADDRESS

[ ] *Customer Number or Bar Code Label* *(Insert Customer No. or Attach bar code label here)* *or* [X] *Correspondence address below*

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Signature	Paul J. Farrell	*Date*	9/29/00

CERTIFICATION UNDER 37 C.F.R. 1.10 I hereby certify that this correspondence and the documents referred to as enclosed are being deposited with the United States Postal Service on date below in an envelope as "Express Mail Post Office to Addressee" Mail Label Number EL484186784US addressed to: Assistant Commissioner for Patents, Box Patent Application, Washington, D.C. 20231.

Dated: September 29, 2000

Theodosios Thomas

PTO/SB/17 (12/99)
Approved for use through 09/30/2000. OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

FEE TRANSMITTAL for FY 2000

Patent fees are subject to annual revision.
Small Entity payments must be supported by a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12. See 37 C.F.R. §§ 1.27 and 1.28.

TOTAL AMOUNT OF PAYMENT ($) 886.00

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Hye-Jeong KIM et al.
Examiner Name	
Group / Art Unit	
Attorney Docket No.	678-529 (P9530)

METHOD OF PAYMENT (check one)

1. [X] The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number: 04-1121

Deposit Account Name: DILWORTH & BARRESE, LLP

[X] Charge Any Additional Fee Required Under 37 CFR §§ 1.16 and 1.17

2. [X] **Payment Enclosed:** [X] Check [ ] Money Order [ ] Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	$690.00
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	690	208	345	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 690.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims	14	-20** =	0	X	$18	=	$0
Independent Claims	5	- 3** =	2	X	$78	=	$156
Multiple Dependent					$260	=	$0

***or number previously paid, if greater; For Reissues, see below*

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim, if not paid
109	78	209	39	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 156.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	380	216	190	Extension for reply within second month	
117	870	217	435	Extension for reply within third month	
118	1,360	218	680	Extension for reply within fourth month	
128	1,850	228	925	Extension for reply within fifth month	
119	300	219	150	Notice of Appeal	
120	300	220	150	Filing a brief in support of an appeal	
121	260	221	130	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,210	241	605	Petition to revive - unintentional	
142	1,210	242	605	Utility issue fee (or reissue)	
143	430	243	215	Design issue fee	
144	580	244	290	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	$40
146	690	246	345	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	690	249	345	For each additional invention to be examined (37 CFR § 1.129(b))	

Other fee (specify) ____________________

Other fee (specify) ____________________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 40

SUBMITTED BY

				Complete (if applicable)	
Name (Print/Type)	Paul J. Farrell	Registration No. (Attorney/Agent)	33,494	Telephone	(516) 228-8484
Signature	Paul J. Farrell			Date	September 29, 2000

CERTIFICATION UNDER 37 C.F.R. § 1.10 I hereby certify that this correspondence and the documents referred to as enclosed are being deposited with the United States Postal Service on date below in an envelope as "Express Mail Post Office to Addressee" Mail Label Number EL484186784US addressed to: Assistant Commissioner for Patents, Box Patent Application, Washington, D.C. 20231.

Dated: September 29, 2000

Theodosios Thomas

Atty. Docket No. 678-529(P9530)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BOX PATENT APPLICATION
Assistant Commissioner for Patents
Washington, D.C. 20231

UTILITY APPLICATION FEE TRANSMITTAL

Sir:

Transmitted herewith for filing is the patent application of

Inventor(s): **Hye-Jeong KIM and Hyun-Kyu LEE**

For: **SYSTEM AND METHOD FOR COMPENSATING TIMING ERROR USING PILOT SYMBOL IN OFDM/CDMA COMMUNICATION SYSTEM**

Enclosed are:

[X] 19 page(s) of specification

[X] 1 page(s) of Abstract

[X] 5 page(s) of claims

[X] 9 sheet(s) of drawing(s) [X] formal [] informal

[X] 2 page(s) of Declaration and Power of Attorney

[X] An Assignment of the invention to Samsung Electronics Co., Ltd.

CERTIFICATION UNDER 37 C.F.R. § 1.10

I hereby certify that this New Application Transmittal and the documents referred to as enclosed therein are being deposited with the United States Postal Service on this date September 29, 2000in an envelope as "Express Mail Post Office to Addressee" Mail Label Number **EL484186784US** addressed to: BOX PATENT APPLICATION, Assistant Commissioner for Patents, Washington, D.C. 20231.

Dated: September 29, 2000

Theodosios Thomas

[X] Certified copy of application

Country	Appln. No.	Filed
Republic of Korea	**1999-41669**	**September 29, 1999**

from which priority under Title 35 United States Code, § 119 is claimed

[ ] is enclosed.

[**X**] will follow.

CALCULATION OF UTILITY APPLICATION FEE

For	Number Filed		Number Extra	Rate	Basic Fee $ 690.00
Total Claims*	14	=	0	x $ 18.00	$ -0-
Independent Claims	5	=	2	x $ 78.00	$ 156.00
Multiple dependent	[ ] yes		Add'l. Fee	$260.00	$ -0-
Claims	[x] no		Add'l. Fee	None	= $ -0-
				TOTAL	**$ 846.00**

[ ] Verified Statement of "Small Entity" Status Under 37 C.F.R. § 1.27. Reduced fees under 37 C.F.R. § 1.9(f) (50% of total) paid herewith $_______.

[X] A check in the amount of **$40.00** to cover the recording of the attached Assignment is enclosed.

[X] A check in the amount of **$846.00** to cover the filing fee(s) is attached.

[ ] Charge fee to Deposit Account No. 04-1121. Order No. ______ TWO DUPLICATE COPIES OF THIS SHEET ARE ATTACHED.

*Includes all independent and single dependent claims and all claims referred to in multiple claims. See 37 C.F.R. § 1.75(c).

[X] Please charge any deficiency as well as any other fee(s) which may become due under 37 C.F.R. § 1.16 and/or 1.17 at any time during the pendency of this application, or credit any overpayment of such fee(s) to Deposit Account No. 04-1121. Also, in the event any extensions of time for responding are required for the pending application(s), please treat this paper as a petition to extend the time as required and charge Deposit Account No. 04-1121 therefor. TWO DUPLICATE COPIES OF THIS SHEET ARE ATTACHED.

Date: September 29, 2000

Paul J. Farrell

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SYSTEM AND METHOD FOR COMPENSATING TIMING ERROR USING PILOT SYMBOL IN OFDM/CDMA COMMUNICATION SYSTEM

PRIORITY

This application claims priority to an application entitled "System and Method for Compensating Timing Error Using Pilot Symbol in OFDM/CDMA Communication System" filed in the Korean Industrial Property Office on September 29, 1999 and assigned Serial No. 99-41669, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a system and method for compensating timing errors in an OFDM/CDMA communication system, and in particular, to a system and method for continuously compensating timing errors by detecting a pilot signal inserted in a symbol unit and using a phase difference line.

2. Description of the Related Art

In general, an OFDM/CDMA (Orthogonal Frequency Division Multiplexing/Code Division Multiple Access) communication system uses multiple carriers having orthogonality. In the OFDM/CDMA communication system, it is very important to maintain the orthogonality among the multiple carriers during demodulation, since maintaining the orthogonality among the multiple carriers at the receiver is closely related to the call quality. A receiver in the OFDM/CDMA communication system also performs frame sync

(synchronization), sampling sync and carrier frequency sync in order to demodulate an OFDM signal transmitted from a transmitter, similar to receivers in other mobile communication systems. Since the OFDM/CDMA communication system must maintain the orthogonality during demodulation by using multiple carriers, it is necessary to perform accurate synchronization.

FIG. 1 illustrates a block diagram of a general OFDM/CDMA communication system, and FIG. 2 illustrates a general method for inserting pilot signals. A description of FIGS. 1 and 2 follows below.

The structure of a transmitter in a general OFDM/CDMA communication system is illustrated in FIG. 1. A pilot sample inserter 101 generally receives a data symbol comprised of N spread data samples and inserts a pilot sample at regular intervals as shown in FIG. 2. The pilot sample inserting method is divided into (1) an inserting method for delaying actual sample data in a position where the pilot sample is to be inserted; (2) a puncturing method for inserting-after-puncturing the actual sample data (i.e., puncturing a specific bit and then inserting the actual sample data in the bit-punctured position). In the description hereinbelow, the puncturing method is used for pilot sample insertion. The data symbol is a signal spread with a code having a rate of N times. A serial/parallel (S/P) converter 103 separates the pilot symbol output from the pilot sample inserter 101 into N data samples, and provides the separated data samples in parallel to an inverse fast Fourier transform (IFFT) block 105. The IFFT 105 performs inverse fast Fourier transform, i.e., OFDM modulation on the N data samples output from the S/P converter 103, and outputs the N OFDM-modulated OFDM data samples in parallel. A parallel/serial (P/S) converter 106 receives in parallel the OFDM data samples output from the IFFT 105, and outputs an OFDM symbol comprised of N samples to a guard interval inserter 107. The guard

interval inserter 107 then inserts, at the head of the OFDM symbol, a guard interval determined by copying the last G data samples (hereinafter, referred to as "copied data samples") out of the N OFDM data samples. A digital-to-analog converter (DAC) 109 converts the OFDM symbol output from the guard interval inserter 107 to an analog OFDM signal and transmits the converted analog OFDM signal.

The OFDM signal transmitted by the transmitter is received by an analog-to-digital converter (ADC) 111 of a receiver. The ADC 111 converts the received OFDM signal to a digital OFDM symbol comprised of a guard interval and N OFDM data samples and provides the converted OFDM symbol to a guard interval remover 112. The guard interval remover 112 removes the guard interval included in the provided OFDM symbol, and outputs a pure OFDM symbol comprised of N OFDM data samples. The ADC 111 and the guard interval remover 112 operate according to a prescribed timing error estimation signal. An S/P converter 113 separates the OFDM symbol output from the guard interval remover 112 into N OFDM data samples, and outputs the N OFDM data samples in parallel. A fast Fourier transform (FFT) block 114 performs fast Fourier transform, i.e., OFDM demodulation on the N data samples received in parallel from the S/P converter 113, and outputs N OFDM-demodulated data samples. The N data samples are converted to a serial data symbol by a P/S converter 115 and then provided to a pilot sample detector 116. The pilot sample detector 116 detects pilot data samples inserted in the data symbol output from the P/S converter 115, and provides the detected pilot data samples to a timing compensator 117 and the data samples to a despreader 119. Receiving the pilot data samples from the pilot sample detector 116, the timing compensator 117 calculates a timing error using the FFT property shown in Equation (1) below, compensates the calculated timing error, and outputs

a timing error estimation signal to the ADC 111 and the guard interval remover 112.

$$x[n-n_0] \Leftrightarrow X(k)W_N^{k_{n0}}, \quad \text{where } W_N = e^{-j\frac{2\pi}{N}} \quad \ldots\ldots (1)$$

In Equation (1), $x[n-n_0]$ indicates a transmission signal which is time-delayed by n_0, and $X(k)W_N^{k_{n0}}$ indicates a received signal which is linear phase shifted by $W_N^{k_{n0}}$ according to the delay time n_0.

A detailed operation of the timing compensator 117 will be described in detail with reference to Equation (1). The timing compensator 117 calculates a difference between a phase of the pilot sample detected by the pilot sample detector 116 and a previously known reference phase, and estimates a timing error using a fluctuation of the calculated difference value. The despreader 119 despreads the data symbol received from the pilot sample detector 116.

As described above, the OFDM/CDMA communication system has two types of timing compensation methods.

The first method is to insert a pilot data sample between original data samples in a specific period or pattern. In this case, the OFDM/CDMA communication system processes the data in a symbol unit at the receiver, since the respective samples in one symbol have the same information. However, when this method is used, the data is shifted back by the number of the pilot samples, so that transmission is not performed in the symbol unit. Further, the position of the sample where the actual data symbol starts is continuously changed, so that the receiver must continuously search the start position of the actual data symbol.

The second method is to puncture some of the actual data samples in a specific period or pattern and insert a pilot sample in the punctured data sample position. In this case, significant noise is generated because the sample data, which is the original data, is punctured when the receiver despreads the actual sample data.

Further, in the receiver, a frequency error in a time domain is expressed by timing changing in a frequency domain after passing the FFT stage. If the frequency error larger than a sub-carrier band passes the FFT stage, one or more samples are shifted, so that another data sample is located in a position where the pilot data sample is to be located. This is because the positions of the pilot data samples in the symbol are not continuous. In this case, it is not possible to obtain required information. Thus, it is not possible to compensate for the timing error in the conventional method.

More specifically, in an ideal system, a phase difference between the received pilot data sample and the reference data sample is $(2\pi n_e k)/N$ and has a linear property with respect to an index 'k', as shown in Equation (1). That is, it is possible to calculate a timing error n_e by calculating a slope for the index 'k' of the phase difference and then dividing the calculated slope by $2\pi/N$. However, due to the phase characteristic in which the value is limited to $\pm\pi$, it is not possible to obtain a linear phase difference line and the phase difference line has an abrupt fluctuation of about $\pm 2\pi$ at around $\pm\pi$. In this case, a process for converting the phase difference line to a linear phase difference line is required. This raises a more serous problem in a non-ideal system. A factor affecting the phase difference line includes a frequency error, a common phase error (CPE), noises, and non-cyclic shift.

In the receiver, a frequency error k_e can be divided into a frequency error k_{ei} of a multiple of one-data sample interval and a frequency error k_{ed} of within one-data sample interval. The frequency error k_e in the time domain is expressed in timing changing in the frequency domain after passing the FFT stage, and if a frequency error k_{ei} occurred longer than a one-sample period passes the FFT stage, the respective pilot data samples in the data symbol are shifted by over one data sample, so that a data sample other than the original pilot data sample is received, thus making it difficult to calculate an accurate phase difference. In addition, the frequency error k_{ed} also affects the phase difference line caused by fluctuation of the phase. In this case, the phase difference line is formed as shown in FIG. 3. In this phase difference line, the dots denote the pilot data samples.

Therefore, in order to use the conventional timing error compensation method, the OFDM/CDMA communication system should necessarily compensate the frequency error of over the sub-carrier band before timing estimation.

The number of pilot data samples is also an important factor affecting the performance. As the timing error increases more and more, the fluctuation of the phase increases and the number of transitions also increases, so that many pilot data samples are required. For example, one data symbol requires the pilot samples over four times of the timing error.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a system and method for inserting pilot samples in a symbol unit before transmission in a transmitter for an OFDM/CDMA communication system.

It is another object of the present invention to provide a system and method for compensating a timing error by detecting pilot data samples in a symbol unit in a receiver for an OFDM/CDMA communication system having a transmitter for inserting the pilot data samples in the symbol unit before transmission.

It is yet another object of the present invention to provide a system and method for compensating a timing error by calculating a linear phase difference line by detecting pilot data samples in a symbol unit in a receiver for an OFDM/CDMA communication system having a transmitter for inserting the pilot data samples in the symbol unit before transmission.

To achieve the above and other objects, a timing error compensation system in an OFMD/CDMA communication system is provided, which includes an analog-to-digital converter for converting an OFDM signal, comprised of a data symbol stream in which a pilot symbol is inserted at intervals of a prescribed number of data symbols, received from a transmitter, to a digital OFDM symbol stream by prescribed sampling synchronization, a guard interval remover for removing a guard interval inserted in the OFDM symbol by prescribed frame synchronization, and a fast Fourier transform (FFT) device for performing fast Fourier transform on the guard interval-removed OFDM symbol and outputting a data symbol stream. In the time error compensation system, a pilot symbol detector receives the data symbol stream and detects the pilot symbols inserted in the data symbol stream at prescribed intervals. A timing compensator determines a linear phase difference line for the detected pilot symbol, generates a timing error estimation signal according to the determined linear phase difference line, and provides the timing error estimation signal to the analog-to-digital converter and

the guard interval remover so as to determine the sampling synchronization and the frame synchronization.

Preferably, the timing compensator comprises a phase detector for detecting a phase of the pilot symbol in a sample data unit; a phase difference detector for detecting a phase difference between the detected phase of the pilot sample and a reference phase and converting the detected phase difference to a value within a specific range; a phase fluctuation estimator for determining a phase difference line by accumulating the phase difference in a symbol unit, and counting the number of transitions in the phase difference line; and a timing error estimation signal generator for generating a timing error estimation signal for compensating a timing error according to the count value of the transition number.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a block diagram illustrating a conventional OFDM/CDMA communication system;

FIG. 2 is a diagram illustrating a method for inserting pilot samples in the conventional OFDM/CDMA communication system;

FIG. 3 is a diagram illustrating a phase difference line in the conventional OFDM/CDMA communication system;

FIG. 4 is a block diagram illustrating an OFDM/CDMA communication system according to an embodiment of the present invention;

FIG. 5 is a diagram illustrating a method for inserting pilot symbols in the OFDM/CDMA communication system according to an embodiment of the present invention;

FIG. 6 is a diagram illustrating a phase difference line in the OFDM/CDMA communication system according to an embodiment of the present invention;

FIG. 7 is a detailed block diagram illustrating the timing compensator of FIG. 4;

FIG. 8 is a flow chart illustrating a method for compensating a timing error using a pilot symbol in the timing compensator; and

FIGs. 9A and 9B are diagrams illustrating a phase difference line in the OFDM/CDMA communication system according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail.

The invention is based on the fact that a fluctuation of the timing error value, such as a sampling frequency offset or a sampling phase offset, according to a time is not so high in the communication system. This means that data samples within a specific time period may be considered to have the same timing error values. That is, it is enough to compensate the timing error only once for the data samples received in the above time period. A period of inserting the pilot symbol in the symbol unit may be determined according to performance of an oscillator for generating a sampling clock, or may be properly determined such that timing compensation should be performed within a sync time required by the system.

FIG. 4 illustrates a block diagram of an OFDM/CDMA communication system according to an embodiment of the present invention. A structure of the OFDM/CDMA communication system will be described below with reference to FIG. 4.

In a transmitter, a multiplier 131 multiplies an actual data symbol by a code having a rate of N times, to spread input data in a symbol unit. Here, one data symbol is comprised of N data samples. A pilot symbol inserter 133 receives the spread data symbol stream and inserts pilot data samples in the symbol unit according to the above-stated inserting method. Although the pilot symbol inserter 133 is positioned in a pre-stage of a S/P converter 135 in FIG. 4, it can also be positioned in a post-stage of the S/P converter 135. In the following exemplary description, the pilot symbol inserter 133 is positioned in the pre-stage of the S/P converter 135. The S/P converter 135 receives the data symbol or the pilot symbol output from the pilot symbol inserter 133 and outputs N data samples in parallel. An IFFT 137 performs inverse fast Fourier transform on the data samples received from the S/P converter 135, and outputs an OFDM symbol. A guard interval inserter 139 inserts a guard interval in the OFDM symbol, and a DAC 141

converts the guard interval-inserted OFDM symbol to an analog OFDM signal and transmits the converted analog OFDM signal.

In a receiver, an ADC 145 converts the OFDM signal transmitted from the transmitter to a digital OFDM symbol including a guard interval according to a prescribed timing sync signal, and provides the converted digital OFDM symbol to a guard interval remover 147. The guard interval remover 147 detects and removes the guard interval included in the OFDM symbol received from the ADC 145 according to the timing sync signal. An FFT 149 performs fast Fourier transform on the OFDM symbol output from the guard interval remover 147, and outputs N data samples in parallel. A P/S converter 150 converts the N parallel data samples to a serial data symbol, and provides the converted serial data symbol to a pilot symbol detector 152. The pilot symbol detector 152 detects a pilot symbol from the input data symbol stream, and provides the detected pilot symbol to a timing compensator 151 and the pilot symbol-removed data symbols to a despreader 153. The despreader 153 despreads the data symbols provided from the P/S converter 150. The timing compensator 151 estimates a timing error using the pilot symbol from the pilot symbol detector 152 and the original pilot symbol previously known to the receiver, and provides a timing error estimation signal for compensating the estimated timing error to the ADC 145.

Operation of the receiver will be described in detail hereinbelow.

A frequency error occurs during actual transmission of the OFDM/CDMA communication system. If a frequency error per symbol unit is k_e[Hz/symbol] and a frequency error of an n-th sample in an m-th symbol is $k_m[n]$, the frequency error $k_m[n]$ can be expressed as

$$k_m[n] = \frac{k_e}{N} m(N+G) + \frac{k_e}{N} n \quad \ldots\ldots (2)$$

If an input signal to a pre-stage of the guard interval inserter 139 of the transmitter is $X_m[n]$, and an input signal to the FFT 149 and an output signal from the FFT 149 after guard interval removing are $y'_m[k]$ and $y'_m[n]$, respectively, then the signals $y'_m[k]$ and $y'_m[n]$ can be expressed as

$$\begin{aligned} y'_m[n] &= x_m[n] e^{j2\pi k_m[n]} \cdot e^{P_e} + W_m[n] \\ &= x_m[n] e^{\frac{j2\pi k_{e[m(N+G)+n]}}{N}} \cdot e^{jP_e} + W_m[n] \\ &= x_m[n] e^{\frac{j2\pi k_e n}{N}} \cdot e^{\frac{2\pi k_e m(N+G)}{N}} \cdot e^{jP_e} + W_m[n] \quad \ldots\ldots (3) \end{aligned}$$

where, n=0,1,2,. . . ,N-1 : the number of samples

m=0, 1,2,. . . ,N-1 : the number of symbols

N : the number of samples per symbol

G : the number of samples per guard interval

$K_m[n]$: a frequency offset of an nth sample in an mth symbol

P_e : common phase error

$W_m[n]$: AWGN of an mth symbol

If a timing error such as an FFT start point detection error, a timing frequency offset and a timing phase offset is n_e, an input signal to the FFT 149 after guard interval removing can be expressed as

$$\begin{aligned} y'_m(k) &= y_m[n-n_e] \\ &= x_m[n-n_e] e^{\frac{j2\pi k_e(n-n_e)}{N}} \cdot e^{2\pi k_e \frac{m(N+G)}{N}} \cdot e^{jP_e} + W_m[n-n_e] \quad \ldots\ldots (4) \end{aligned}$$

After the signal y'$_m$(k) passes the FFT 149, the frequency error is converted to a shift of the signal and the timing error is converted to a fluctuation of the phase according to the FFT characteristics, as follows:

$$Y'_m(k) = X_m(k-k_e)e^{\frac{j2\pi(k-k_e)n_e}{N}} \cdot e^{\frac{2\pi k_e m(N+G)}{N}} \cdot e^{jp_e} + W_m[k-k_e]$$
$$= X_m(k-k_e)e^{\frac{j2\pi k n_e}{N}} \cdot e^{-j\frac{2\pi k_e n_e}{N}} \cdot e^{\frac{2\pi k_e m(N+G)}{N}} \cdot e^{jp_e} + W_m[k-k_e] \;.....(5)$$

If the timing compensator 151 detects only the pilot symbol from Y'$_m$(k),

$$Y'_m(k) = X_m(k-k_e)\cdot e^{\frac{j2\pi k n_e}{N}} \cdot e^{-j\frac{2\pi k_e n_e}{N}} \cdot e^{\frac{2\pi k_e m(N+G)}{N}} \cdot e^{jp_e} + W_m[k-k_e] \;.....(6)$$

where $m = 0, l-1, 2l-1, \ldots$

In Equation (6), 'l' denotes an insert period of the pilot symbol. A phase of the received pilot symbol can be calculated by Equation (7) below.

$$\angle Y'_m(k) = \angle X_m(k-k_e) + \frac{2\pi n_e}{N}k - \frac{2\pi n_e k_e}{N} + 2\pi k_e \frac{m(N+G)}{N} + p_e + \angle W_m[k-k_e] \;...(7)$$

In Equation (7), the second term indicates a fluctuation of the phase according to the index 'k', the next 3 terms indicate constant phase offsets, and the last term indicates a fluctuation of the phase.

Since the receiver has a reference phase $\angle X_m(k)$, a difference between a phase of the received pilot symbol and the reference phase is calculated as follows, to calculate the timing error n_e,

$$diff_{phase}(k) = \angle Y'_m(k) - \angle X_m(k)$$

$$= \angle X_m(k-k_e) - \angle X_m(k) + \frac{2\pi n_e}{N}k - \frac{2\pi n_e k_e}{N}$$

$$+ 2\pi k_e \frac{m(N+G)}{N} + p_e + \angle W_m[k-k_e] \quad \ldots\ldots (8)$$

In Equation (8), if the frequency error K_e is 0, $\angle X_m(k-k_e) - \angle X_m(k) = 0$. Hence, the phase difference is expressed as a linear line including the fluctuation($\angle W_m[k\text{-}k_e]$) due to the noise for the index 'k'. As a result, it is possible to estimate the timing error n_e using the equation (8) by estimating a slope, of the phase difference line. Otherwise, if the frequency error k_e is not 0, $\angle X_m(k-k_e) - \angle X_m(k) \neq 0$. Hence, it is difficult to calculate the timing error n_e in the above method. Therefore, in an exemplary embodiment of the present invention, all the samples in a pilot symbol have the same phase, to calculate the timing error even when the frequency error occurs. To this end, a method for outputting the same signal for the real part and the imaginary part of the pilot symbol is used. In this case, if an influence of the channel is ignored, it is possible to calculate the timing error without any influence from the frequency error.

The frequency error k_e can be divided into a frequency error k_{ei} of a multiple of a one-sample period and a frequency error k_{ed} having a value within the one-sample period. When the pilot samples with same frequence are to be inserted in the symbol unit as above , K_{ei} has no influence on the phase difference line, and since k_{ed} has a constant phase offset, it never affects the slope.

FIG. 5 illustrates a method for inserting pilot symbols in an OFDM/CDMA communication system according to an embodiment of the present invention. FIG. 5 shows an example where the pilot symbol is inserted at 5-symbol intervals.

FIG. 6 illustrates a phase difference line in an OFDM/CDMA communication system according to an embodiment of the present invention. It is possible to more efficiently reduce the influence of the noise by inserting the pilot signal in the symbol unit as compared with the case where the pilot signal is inserted in the sample unit, thereby making it possible to calculate an accurate timing error.

FIG. 7 illustrates a detailed block diagram of the timing compensator 151 of FIG. 4, and FIG. 8 illustrates a timing error compensation method according to an embodiment of the present invention.

Referring to FIGS. 7 and 8, a phase detector 161 detects a phase of the pilot sample provided in the symbol unit from the pilot symbol detector 152, and provides the detected phase of the pilot sample to a phase difference detector 163. The phase difference detector 163 calculates a phase difference between the detected phase of the pilot sample and a reference phase, which is provided from the upper layer and known to the receiver, converts the calculated phase difference to a value within $\pm\pi$, and provides the resulting phase difference to a phase fluctuation estimator 165 (Step 801).

The phase fluctuation estimator 165 receives the phase difference value, and counts the number of transitions of the phase difference line in consideration of the direction (Step 803). Here, the transition count result and its sign determined in consideration of the direction together indicate a direction of the timing error, which is fast or slow with respect to the reference signal, and its absolute value indicates a timing error of ((a multiple of the sample period)+1) {(timing error/sample period)+1}. When a noise and a constant phase offset are included in the received signal, fluctuation occurs as a result of the noise. As a

result, when the noise line value approaches near ±π, undesirable transitions occur several times. In the invention, it is possible to reduce the influence of noise by considering both the direction and the number of transitions, based on the fact that the number of transitions due to the noise is equal in the positive (+) and negative (-) directions.

After counting the transition value, the phase fluctuation estimator 165 outputs the count value to a timing error compensation signal generator 167. The timing error compensation signal generator 167 generates a timing error compensation signal according to the count value. When generating the timing error compensation signal, the timing error is divided into the timing error n_{ei} of over the sample period and the timing error n_{ed} within the sample period, and whether the timing error is a value over the sample period or a value within the sample period is determined according to whether the transition count value nt is greater than 1 or not (Step 805).

If it is determined in step 805 that the transition count value $|nt|$ is an integer of greater than '1', the timing error is repeatedly estimated according to the transition count value nt until the transition count value nt becomes an absolute value of less than '1'. That is, the timing error compensation signal generator 167 receives an estimation signal of the timing error n_{ei}, the length of which is a multiple of the sample period, from the phase fluctuation estimator 165, generates a timing error estimation signal for compensating the timing error, the length of which is a multiple of the sample period, according to the n_{ei} estimation signal(nt), and provides the generated timing error estimation signal to the ADC 145 (Step 807).

Otherwise, when the transition count value $|n|$ has an absolute value less than or equal to 1 in step 805, the phase fluctuation estimator 165 generates an estimation signal of a timing error n_{ed} within the sample period (Step 809). That is, it is possible to estimate the timing error n_e using the equation (8) after calculating the slope, of the timing error phase difference line according to the Equation (8). As described above, when the transition count value nt has the absolute value of below '1', it is possible to more accurately calculate the slope, as compared with the case where the slope is calculated after converting the phase difference line of FIG. 9A to the transitionless linear phase difference line of FIG. 9B. Equation (9) below may be used to calculate the timing error while canceling the influence of the transitions due to the noise.

$$P'_{k+1} = \begin{vmatrix} P_{k+1} - 2i\pi, & \text{if } (2i-1)\pi \langle (P_{k+1} - P'_k) \langle (2i+1)\pi \\ P_{k+1} + 2i\pi, & \text{if } -(2i+1)\pi \langle (P_{k+1} - P'_k) \langle -(2i-1)\pi \\ P_{k+1}, & otherwise \end{vmatrix} \quad .....(9)$$

where P_k denotes phase values of the phase difference line with transitions, and P_k' denotes phase values converted such that no transition exists.

In step 809, the timing error estimation signal generator 167 removes the influence of the noises from the phase difference line, including the fluctuation due to noise, divides the phase difference line by N/2 samples according to Equations (10-1) to (10-3) below to calculate a value being close to the original slope, and calculates two average values of the N/2 samples. Thereafter, the noise influence-reduced slope can be obtained from the two average values in accordance with Equation (11) below.

$$a, 2a, ..., \frac{N}{2}a, (\frac{N}{2}+1)a, ..., (N-1)a, Na \quad .....(10\text{-}1)$$

$$a+w_1, 2a+w_2, \ldots, \frac{N}{2}a+w_{\frac{N}{2}}, (\frac{N}{2}+1)a+w_{\frac{N}{2}+1}, (N-1)a+w_{N-1}, Na+w_N \ldots (10\text{-}2)$$

$$avg_{first}=\frac{(a+2a+\ldots+\frac{N}{2}a)+(w_1+w_2+\ldots+w_{\frac{N}{2}})}{\frac{N}{2}} \quad \ldots\ldots (10\text{-}3)$$

$$avg_{\text{second}}=\frac{((\frac{N}{2}+1)a+(\frac{N}{2}+2)a+\ldots+Na)+(w_{\frac{N}{2}+1}+w_{\frac{N}{2}+2}+\ldots+w_{\frac{N}{2}})}{N}$$

where, N : the number of samples per symbol,

w : noise, and

a : slope.

Equation (10-1) indicates respective sample values of the phase difference line having a slope 'a', and Equation (10-2) indicates respective sample values when noise is included therein. Further, Equation (10-3) indicates average values of first N/2 samples and next N/2 samples.

In addition, the phase fluctuation estimator 165 calculates a slope of the phase difference line based on Equation (11) and outputs the n_{ed} compensation signal. Then, in step 811, the timing error estimation signal generator 167 receives n_{ed} estimation signal, and outputs to the ADC 145 a timing error estimation signal for compensating the timing error according to the n_{ed} estimation signal.

$$slope=\frac{avg_{second}-avg_{first}}{\frac{N}{2}}\approx a \quad \ldots\ldots (11)$$

As described above, the invention can remove the influence of the frequency error during timing error estimation. Therefore, it is possible to compensate the timing error even when the frequency error is not completely compensated. In addition, the invention can increase an accuracy of compensating the timing error by removing the influence of the noises and the influence of undesired transitions.

While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A timing error compensation system in an OFDM/CDMA (Orthogonal Frequency Division Multiplexing/Code Division Multiple Access) communication system, comprising:

a pilot symbol inserter for receiving a spread data symbol stream, and periodically inserting N pilot symbols each having a same phase using a specific period in a symbol unit to compensate a timing error of a receiver.

2. A timing error compensation system in an OFDM/CDMA communication system said OFDM/CDMA communication system including an analog-to-digital converter which converts an OFDM signal to a digital OFDM symbol stream using sampling synchronization; a data symbol stream received from a transmitter, in which a pilot symbol is inserted at intervals of a predetermined number of data symbols; a guard interval remover for removing a guard interval inserted in the OFDM symbol using frame synchronization; and a fast Fourier transform (FFT) device for performing fast Fourier transform on the guard interval-removed OFDM symbol and outputting a data symbol stream; said timing error compensation system comprising:

a pilot symbol detector which receives the data symbol stream and detecting the pilot symbols inserted in the data symbol stream at predetermined intervals in a symbol unit; and

a timing compensator which determines a linear phase difference line for the detected pilot symbol using the pilot symbol and a reference symbol previously known by the receiver, generates a timing error estimation signal according to the determined linear phase difference line, and provides the timing error estimation signal to the analog-to-digital converter and the guard interval

remover so as to determine the sampling synchronization and the frame synchronization.

3. The timing error compensation system as claimed in claim 2, wherein the timing compensator comprises:

a phase detector to detect a phase of the pilot symbol in a sample data unit;

a phase difference detector to detect a phase difference between the detected phase of the pilot sample and a reference phase and converting the detected phase difference to a value within a specific range;

a phase fluctuation estimator to determine a phase difference line by accumulating the phase difference in a symbol unit, and counting the number of transitions in the phase difference line; and

a timing error compensation signal generator to generate a timing error estimation signal to compensate for a timing error according to the count value of the transition number.

4. The timing error compensation system as claimed in claim 3, wherein the phase difference between the phase of the pilot sample and the reference phase is calculated by

$$\begin{aligned} diff_{phase}(k) &= \angle Y'_m(k) - \angle X_m(k) \\ &= \angle X_m(k-k_e) - \angle X_m(k) + \frac{2\pi n_e}{N}k - \frac{2\pi n_e k_e}{N} \\ &\quad + 2\pi k_e \frac{m(N+G)}{N} + p_e + \angle W_m[k-k_e] \end{aligned}$$

5. A timing error compensation system in an OFDM/CDMA communication system, which receives an OFDM signal, said OFDM/CDMA

communication system comprised of a data symbol stream received from a transmitter, in which a pilot symbol is inserted at periods of a prescribed number of data symbols and outputting a data symbol stream through a fast Fourier transform, said timing error compensation system comprising:

a pilot symbol detector to detect a pilot symbol inserted in the data symbol stream at prescribed intervals;

a timing compensator to determine a linear phase difference line for the detected pilot symbol, and generate a timing error estimation signal according to the determined linear phase difference line;

an analog-to-digital converter to determine sampling synchronization according to the timing error estimation signal from the timing compensator, and converting the OFDM signal to a digital OFDM symbol by the determined sampling synchronization; and

a guard interval remover to determine frame synchronization according to the timing error signal from the timing compensator, and to remove a guard interval inserted in the OFDM symbol from the analog-to-digital converter.

6. The timing error compensation system as claimed in claim 5, wherein the timing compensator comprises:

a phase detector to detect a phase of the pilot symbol in a sample data unit;

a phase difference detector to detect a phase difference between the detected phase of the pilot sample and a reference phase and converting the detected phase difference to a value within a specific range;

a phase fluctuation estimator to determine a phase difference line by accumulating the phase difference in a symbol unit, and counting the number of transitions in the phase difference line; and

a timing error estimation signal generator to generate a timing error estimation signal for compensating a timing error according to the count value of the transition number.

7. The timing error compensation system as claimed in claim 6, wherein a timing error estimation signal for compensating a timing error within a sample period is generated when the transition number count value is less than 1, and a timing error estimation signal for compensating a timing error over the sample period is generated when the transition number count value is greater than 1.

8. A method for compensating a timing error in an OFDM system, which inserts a pilot symbol in a data symbol stream in a symbol unit at intervals of a predetermined number of data symbols, the method comprising the steps of:

detecting a pilot symbol inserted in a received data symbol stream at predetermined intervals;

calculating a phase difference between the detected phase of the pilot symbol and a reference phase, and converting the calculated phase to a phase difference value within a specific range; and

compensating a timing error using a transition number of the converted phase difference value.

9. The method as claimed in claim 8, wherein the phase difference range is $\pm\pi$.

10. A method for compensating a timing error in an OFDM system, which inserts a pilot symbol in a data symbol stream in a symbol unit at intervals of a predetermined number of data symbols, the method comprising the steps of:

detecting a pilot symbol inserted in a received data symbol stream at predetermined intervals;

detecting a phase of the detected pilot symbol in a sample data unit;

calculating a phase difference between the detected phase of the pilot symbol and a reference phase, and converting the calculated phase to a phase difference value within a specific range;

counting the number of transitions within a specific range for the respective data samples;

determining whether the count value is larger than a prescribed value; and

compensating a timing error, when the count value is larger than the prescribed value.

11. The method as claimed in claim 10, comprising the additional step of compensating, when the count value is less than the prescribed value, the timing error by converting the count value to a phase difference line and estimating a slope of the phase difference line.

12. The method as claimed in claim 11, wherein the slope of the phase difference line is calculated by

$$slope = \frac{avg_{second} - avg_{first}}{\frac{N}{2}} \approx a$$

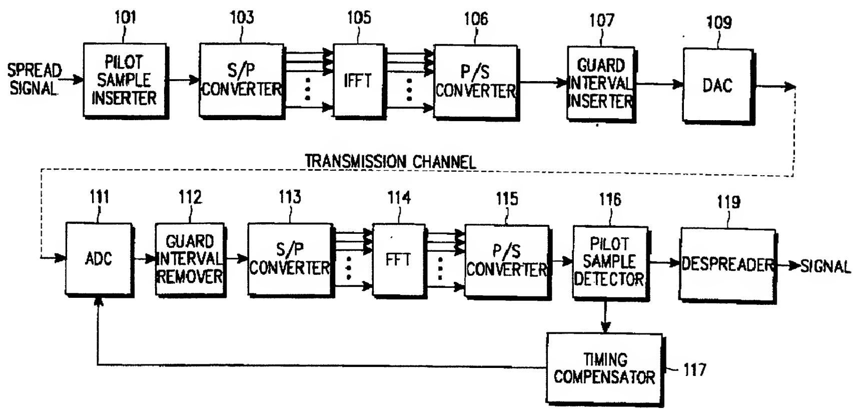
13. The method as claimed in claim 10, wherein the prescribed value is '1'.

14. The method as claimed in claim 10, wherein the phase difference range is $\pm\pi$.

ABSTRACT OF THE DISCLOSURE

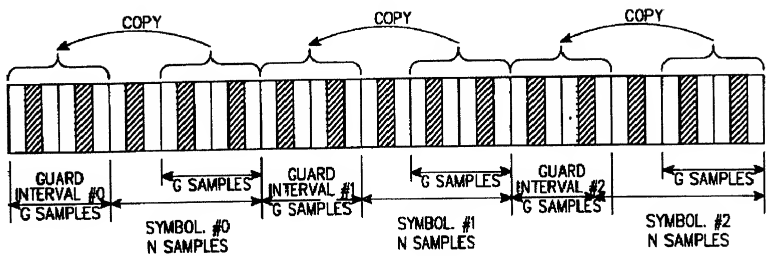
A timing error compensation system in an OFMD/CDMA communication system includes an analog-to-digital converter for converting an OFDM signal, comprised of a data symbol stream in which a pilot symbol is inserted at intervals of a prescribed number of data symbols, received from a transmitter, to a digital OFDM symbol stream by prescribed sampling synchronization, a guard interval remover for removing a guard interval inserted in the OFDM symbol by prescribed frame synchronization, and a fast Fourier transform (FFT) device for performing fast Fourier transform on the guard interval-removed OFDM symbol and outputting a data symbol stream. In the time error compensation system, a pilot symbol detector receives the data symbol stream and detects the pilot symbols inserted in the data symbol stream at prescribed intervals. A timing compensator determines a linear phase difference line for the detected pilot symbol, generates a timing error estimation signal according to the determined linear phase difference line, and provides the timing error estimation signal to the analog-to-digital converter and the guard interval remover so as to determine the sampling synchronization and the frame synchronization.

FIG. 1



SPREAD SIGNAL
101
PILOT SAMPLE INSERTER
103
S/P CONVERTER
105
IFFT
106
P/S CONVERTER
107
GUARD INTERVAL INSERTER
109
DAC
TRANSMISSION CHANNEL
111
ADC
112
GUARD INTERVAL REMOVER
113
S/P CONVERTER
114
FFT
115
P/S CONVERTER
116
PILOT SAMPLE DETECTOR
119
DESPREADER
SIGNAL
TIMING COMPENSATOR
117

FIG. 2



COPY
COPY
COPY
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G SAMPLES
G SAMPLES
SYMBOL. #0
N SAMPLES
GUARD INTERVAL #1
G SAMPLES
G SAMPLES
SYMBOL. #1
N SAMPLES
GUARD INTERVAL #2
G SAMPLES
G SAMPLES
SYMBOL. #2
N SAMPLES

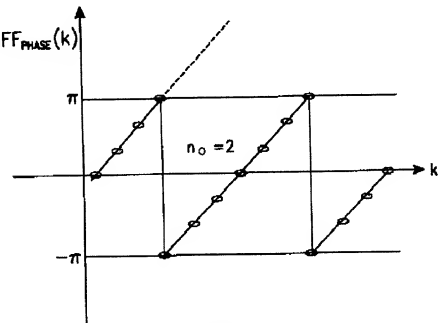
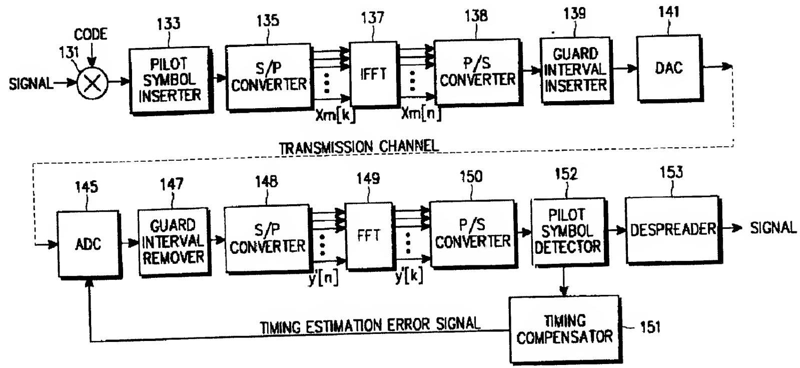


FIG. 3

FIG. 4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PILOT SYMBOL INSERTER
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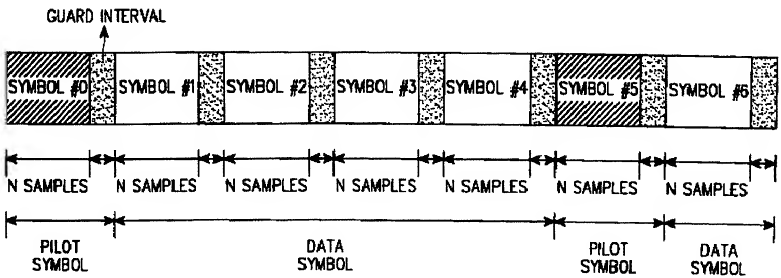
S/P CONVERTER
Xm[k]
137
IFFT
Xm[n]
138
P/S CONVERTER
139
GUARD INTERVAL INSERTER
141
DAC
TRANSMISSION CHANNEL
145
ADC
147
GUARD INTERVAL REMOVER
148
S/P CONVERTER
y'[n]
149
FFT
y'[k]
150
P/S CONVERTER
152
PILOT SYMBOL DETECTOR
153
DESPREADER
SIGNAL
TIMING COMPENSATOR
151
TIMING ESTIMATION ERROR SIGNAL

FIG. 5


GUARD INTERVAL
SYMBOL #0
SYMBOL #1
SYMBOL #2
SYMBOL #3
SYMBOL #4
SYMBOL #5
SYMBOL #6
N SAMPLES
N SAMPLES
N SAMPLES
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PILOT SYMBOL
DATA SYMBOL
PILOT SYMBOL
DATA SYMBOL

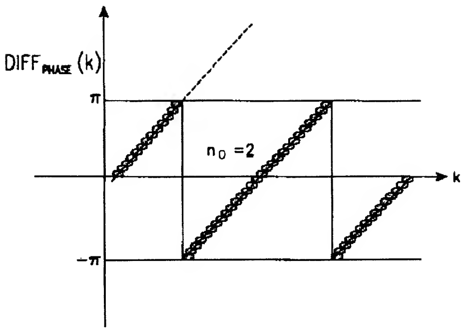
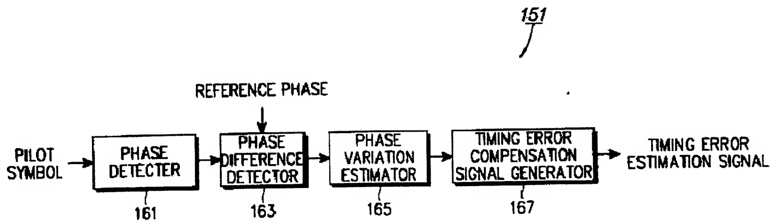


FIG. 6

FIG. 7


151
REFERENCE PHASE
PILOT SYMBOL
PHASE DETECTER
PHASE DIFFERENCE DETECTOR
PHASE VARIATION ESTIMATOR
TIMING ERROR COMPENSATION SIGNAL GENERATOR
TIMING ERROR ESTIMATION SIGNAL
161
163
165
167

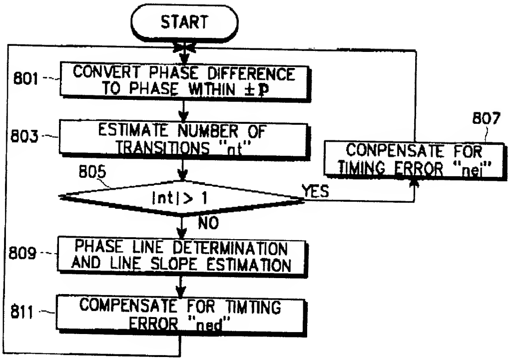

START
801
CONVERT PHASE DIFFERENCE TO PHASE WITHIN ±P
803
ESTIMATE NUMBER OF TRANSITIONS "nt"
805
|nt|> 1
YES
NO
807
CONPENSATE FOR TIMING ERROR "nei"
809
PHASE LINE DETERMINATION AND LINE SLOPE ESTIMATION
811
COMPENSATE FOR TIMTING ERROR "ned"

FIG. 8

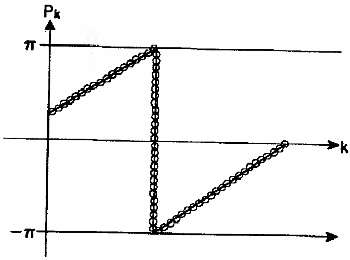


FIG. 9A

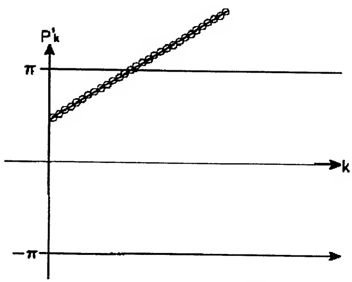


FIG. 9B

PTO/SB/01 (6/96)

DECLARATION

Docket No. 678-529 (P9530)

AS A BELOW NAMED INVENTOR, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe that I am the original, first and sole *(if only one name is listed below)*, or an original, first and joint inventor *(if plural names are listed below)*, of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TITLE: SYSTEM AND METHOD FOR COMPENSATING TIMING ERROR USING PILOT SYMBOL IN OFDM/CDMA COMMUNICATION SYSTEM

the specification of which either is attached hereto or indicates an attorney docket no. 678-529 (P9530) or:

[ ] was filed in the U.S. Patent & Trademark Office on ______ and assigned Serial No. ______,

[ ] and *(if applicable)* was amended on ______ ______.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to patentability and to the examination of this application in accordance with Title 37 of the Code of Federal Regulations §1.56. I hereby claim foreign priority benefits under Title 35, U.S. Code §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designated at least one country other than the United States, or §119(e) of any United States provisional application(s), listed below and have also identified below any foreign applications for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

			Priority Claimed:
1999-41669 *(Application Number)*	Republic of Korea *(Country)*	29/09/1999 *(Day/Month/Year filed)*	Yes [X] No [ ]
(Application Number)	*(Country)*	*(Day/Month/Year filed)*	Yes [ ] No [ ]

I hereby claim the benefit under Title 35, U.S. Code, §120, of any United States application(s), or §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application(s) in the manner provided by the first paragraph of Title 35, U.S. Code, §112, I acknowledge the duty to disclose information material to patentability as defined in Title 37, The Code of Federal Regulations, §1.56(a) which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial Number)	*(Filing Date)*	*(STATUS: patented, pending, abandoned)*
(Application Serial Number)	*(Filing Date)*	*(STATUS: patented, pending, abandoned)*

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I HEREBY DECLARE that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 U.S. Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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